

## ELECTRICALLY OPERATED INJECTOR FOR GASEOUS FUEL

The present invention relates to an electrically operated injector for feeding a gaseous fuel to a cylinder of an internal combustion engine, in accordance with the introduction to the main claim.

An electrically operated injector of the aforesaid type is known to comprise a body connected to a feed conduit for the gaseous fuel or simply gas (such as liquefied petroleum gas, or such as natural gas or hydrogen); this body contains an electromagnetic actuator (electromagnetic coil) acting on a mechanical member or armature movable about a passage which connects a chamber of said body, in communication with the gas feed conduit, to a delivery conduit connected to an outlet for feeding the gas into the corresponding cylinder either directly or indirectly via the intake manifold of the internal combustion engine. Under the influence of the magnetic force generated by the electromagnetic actuator, this mechanical member shuts off or frees said passage in order to prevent or alternatively enable gas to be fed into the cylinder. The generation of this force is controlled by controlling the electrical feed to the actuator by means of a command and control unit for the internal combustion engine operation.

The mechanical member generally consists of a movable disc of ferromagnetic steel which closes the magnetic circuit generated by the actuator or coil. Said disc supports a pin for sliding in respect of the bobbin.

In addition, between the mechanical member and the conduit delivering the gas to the nozzle there is a seal element which enables the delivery conduit to be sealed when the mechanical member is in the position in which it intercepts the gas passage.

An object of the present invention is to provide an electrically operated injector of reliable and safe use, in which the wear of those parts which move relative to

each other, and in particular the mechanical member, the seal element and the delivery conduit, is minimized.

Another object is to provide an electrically operated injector in which turbulence generated within the injector by the passage of gas therethrough and hence the  
5 corresponding pressure drop are minimized in order to maximize the mass flow of gas from the injector.

A further object of the invention is to provide an electrically operated injector in which movement of the mechanical member by the electromagnetic actuator is assured.

10 These and further objects which will be apparent to the expert of the art are attained by an electrically operated injector in accordance with the accompanying claims.

The present invention will be better understood from the accompanying drawing, which is provided by way of non-limiting example and in which:

15 Figure 1 is a cross-section through an electrically operated injector according to the invention;

Figure 2 is an enlarged view of a detail of the injector of Figure 1;

Figure 3 is an enlarged view of the detail indicated by A in Figure 2; and

Figure 4 is an enlarged view of the detail indicated by B in Figure 1 with certain  
20 parts omitted for greater clarity.

With reference to said figures, an electrically operated injector according to the invention is indicated overall by 1 and comprises an electromagnetic actuator 2, a movable mechanical interceptor member 3 arranged to cooperate with a passage 4 for a gaseous fuel or gas directed to a conduit 5 for delivering the  
25 fuel gas to an outlet 6 cooperating with a corresponding cylinder of an internal combustion engine on which the invention is applied. More specifically, the electromagnetic actuator 2 consists of a ferromagnetic steel body 10, in a cavity

11 of which there is positioned an electrical winding 12 surrounding an internal hollow cylindrical part 13 of the body 10. The winding 12 cooperates with the blades 15 of a connector 16 positioned on an upper part 1A of the injector containing the body 10, seal elements 17 being present between the winding  
5 and the part 1A of the injector. The blades are electrically fed, in known manner and neither described nor shown, by the usual electrical circuit of the vehicle to which the said engine belongs.

The conduit 5 forms part of a portion 105 of injector 1, fixed to the body 10 for example by crimping.

10 In the inner cavity 13A of the cylindrical part 13 there is inserted at the top 1A of the injector a fixed setting element 20 cooperating at one end 21 with a spring 22 resting on an end 23 of a pin 24 (advantageously of wear resistant plastic) rigid with the interceptor member 3. The spring 22 has a first end 22A resting  
15 on the flat end 21 of the element 20 and is mounted about a central projecting part 25 thereof. The spring 22 presents a second end 22B resting on the end 23 (also flat) of the pin 24 and mounted about a central projecting part 28 of said end 23. Different positions of the element 20 in the cavity 13A result in different preloading of the spring 22 and hence different thrust actions of this  
20 spring on the pin 24 which, being rigid with the movable mechanical interceptor member 3, transfers said thrust to this latter to adjust its operating conditions. The stroke of the armature is set by virtue of the position of the conduit 5 or of the portion 105 of the injector 1 relative to the body 10, to which it is mechanically fixed.

As stated, the pin 24 is rigid with the interceptor member (or armature) 3 and  
25 has the known function of maintaining this latter to the greatest possible extent perpendicular to its direction of movement along the longitudinal axis K of the injector, in order to maximize the magnetic force generated by the actuator 2

and reduce those vibrations transverse to this movement which act on the spring 22, with the aim of increasing its life.

The interceptor member 3 consists of a movable ferromagnetic steel disc which closes the magnetic circuit generated by the coil defining the electromagnetic actuator 2. This member 3 presents a central recess 30 provided within a first face 3A thereof which faces the actuator 2. The recess 30 receives an end part 31 of the pin 24, said part 31 being fixed in any known manner to said member. A part 35 projects by a distance Z (Figure 3) from the face 3A of the member 3 in proximity to its lateral edge 34. Said projecting part 35 can be obtained, but not exclusively, by inserting into an annular recess 33, provided along a lateral edge 34 and on the face 3A of the member 3, an annular piece arranged to cooperate with the body 10 of the actuator 2 such as to maintain the member 3 detached from said body when said member is drawn towards this latter on using the injector 1. As an alternative, the projecting part 35 can be integral with the member 3. That surface of said part 35 facing the actuator 2 can be flat (as in the figures) or inclined to the edge 34 of the member 3.

More particularly, if the projecting part is defined by the annular piece 35, this latter is constructed preferably of plastic material so as not to interfere with the magnetic field generated between the actuator 2 and the member 3. Other materials having the same function can however be used to form the piece 35.

The projecting part 35 is dimensioned such as to project from the recess 33 by a distance calculated to prevent contact between the interceptor member 3 and the body 10 and such that the closure time of said member onto the conduit 5 is the optimum for correct operation of the injector. By way of example, this distance (indicated by Z in Figure 3) is between 0.07 and 0.13 mm and is preferably 0.1 mm. It is also dimensioned such as to ensure that the magnetic force, present during the "injector open" stage, is sufficient to overcome the

forces that tend involuntarily to reclose the injector (by urging the member 3 onto the conduit 5 and closing the passage 4).

The part 35 also performs the function of absorbing the impact energy of the interceptor member 3 when magnetically drawn onto the body 10, so reducing wear of both said member 3 and said body 10.

On that face 3B facing the conduit 5 and distant from said face 3A there is rigidly attached a seal element 40 of elastomeric material, suitably shaped to prevent seepage of the fuel gas when the injector 1 is electrically deactivated and the passage 4 must be completely intercepted. The seal element 40 also aims to minimize wear of the surfaces of the member 3 and of the conduit 5 when the member moves, and to prevent any rebounding of this latter.

The seal element 40 is fixed to the member 3 in a seat 50 thereof preferably by co-moulding, before complete assembly of the injector 1.

More specifically, said element 40 has a shape tapering towards the conduit 5 which faces it and presents a free end 42 arranged to bearingly cooperate with a free end 43 of said conduit 5 when the passage 4 is intercepted. Preferably, the element 40 is frusto-conical and advantageously presents a dead recess 44 at its end 42 which in this manner assumes, when the injector is closed, an annular form bearing on the end 43 (also annular) of the conduit 5.

The internally hollow frusto-conical element 40 hence presents an outer wall 47 and an inner wall 48. These walls are preferably differently inclined to a straight line M perpendicular to the face 3B of the member 3 and parallel to the axis K, to achieve reduced wear of the element 40 because of its sliding on the end 43 of the conduit 5 when the member 3 intercepts the passage 4. For this reason the angle  $\alpha$  between the wall 47 and the straight line towards the interior of the element 40 is between  $65^\circ$  and  $80^\circ$  and preferably equal to  $72^\circ$ ; likewise the angle  $\beta$  between the wall 48 and said straight line M is between  $35^\circ$  and  $55^\circ$ ,

and advantageously equal to  $47^\circ$ . Also inclined at the same angle is an inner wall 49 of an annular projection 58 of the seat 50 provided in the face 3B of the member 3 and in which there rests a second end 51 of the seal element 40 rigid with the interceptor member 3. The seat 50 also acts as a support, together  
5 with the inner wall 49 of the projection 58, for the seal element 40 so reducing the deformation of this latter under the effect of the load which bears on the interceptor member 3 when the injector 1 is deactivated. In this manner the seal element 40 can effectively act as a limit stop for the movement of the member 3 towards the conduit 5.

- 10 The projection 58 present in the seat 50 presents an outer wall 59 inclined to the straight line M (or to the axis K) by an angle  $\tau$  greater than that of said inner wall 49. The angle  $\tau$  is, for example, between  $70^\circ$  and  $90^\circ$  and preferably equals  $80^\circ$ .

The element 40 projects from the face 3B of the member 3 by a distance  
15 optimized to minimize the turbulence generated by the movement of the gas through the passage 4 and hence the pressure drop in order to maximize the mass flow of gas to the outlet 6. For example, this element could project by a distance (indicated by F in Figure 2) between 0.6 and 1.0 mm, preferably 0.79 mm.

- 20 The outlet 6 is provided at the end of the conduit 5, which presents a first section 5A, close to the end 43 and tapering towards the axis K, a second section 5B which widens about this axis, and a third section 3C (terminating with the outlet 6) of constant cross-section. Between the sections 5A and 5B there is a short conduit portion, indicated by 5D, which acts as a sizing hole for  
25 the gas flow to the outlet. The sizing portion or hole 5D is dimensioned such as to ensure a constant gas flow rate independently of the value of the maximum stroke of the member 3 by the actuator 2 (indicated by X in Figure 2), obviously

within the tolerance range of this stroke.

Finally, the passage 4 cooperates with a chamber 60 present about the conduit 5 and connected to a fuel gas feed line or header 61 via an aperture 62 provided in the portion 105 of the injector 1. The purpose of the chamber 60 is  
5 to damp the acoustic effect generated by the impact of the member 3 against the actuator 2 during the opening of the injector. A seal element 64 is present between the conduit 5 and a known member for supplying gas to the cylinder of the engine (not shown) to which the invention is applied.

By virtue of the invention an electrically operated injector is obtained  
10 representing an improvement over known injectors. Other embodiments of the invention are possible while remaining within the scope of the following claims: for example the seal element 40 can also be of non-tapering cylindrical shape (right cylinder) or be associated with the face 3B of the member 3 in a manner different from that described.